Electron/Photon identification in ATLAS and CMS

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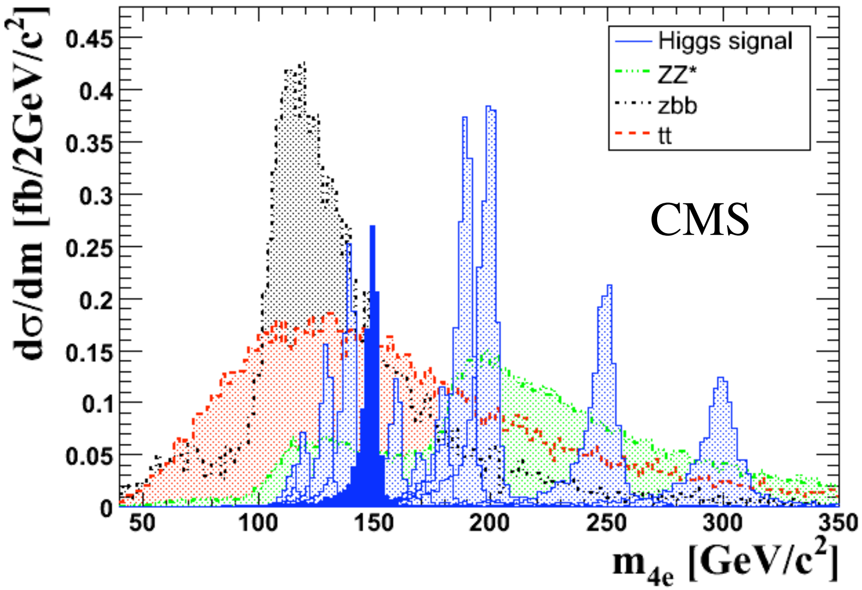
for CMS and ATLAS collaborations

Outline

- Physics motivation
- ATLAS and CMS detectors @LHC
- In situ calibration procedures
- Energy estimation
- Electron tracking
- Material budget effects
- e/jet and γ/π^0 separation
- Soft electrons

Physics motivations

- Higgs search
  - $H \rightarrow \gamma\gamma$
  - $H \rightarrow ZZ^{(*)} \rightarrow 4e$
- BSM
  - TeV resonances
  - Also SUSY
    - Leptonic decays of charginos and neutralinos
- Many SM processes, top, $Z \rightarrow ee$, $W \rightarrow e\nu$
  - Backgrounds to new signals
  - Calibration processes



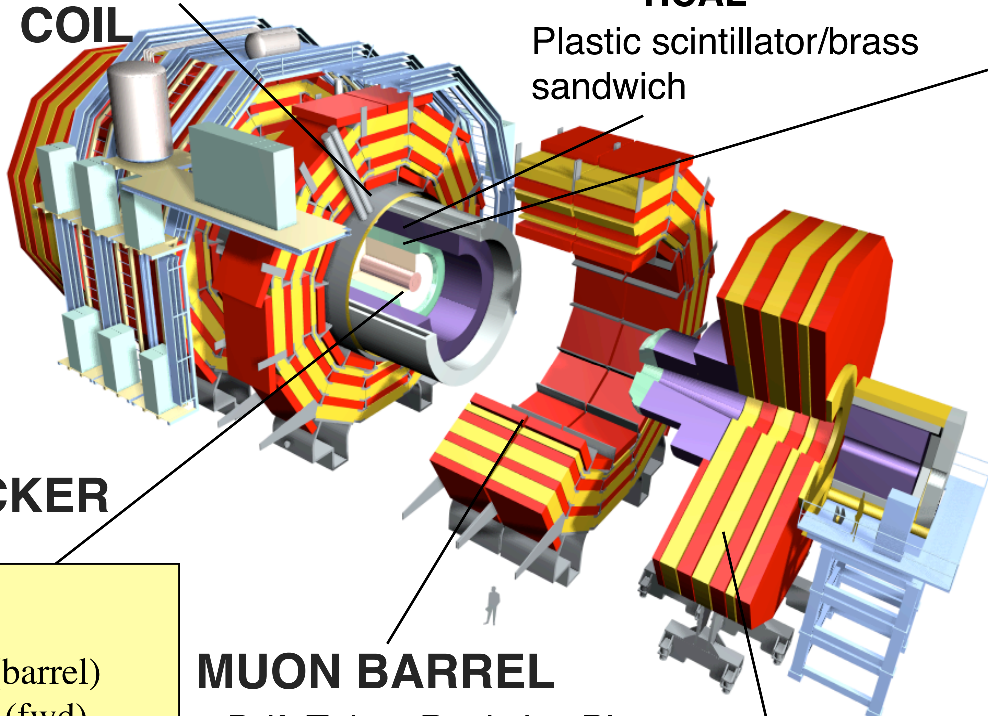
The CMS Detector

SUPERCONDUCTING COIL

HCAL

Plastic scintillator/brass sandwich

CALORIMETERS



TRACKER

PIXEL
3 layers (barrel)
2x2disks (fwd)

SST
>8 hits, depending on η

$|\eta|<2.5$

MUON BARREL

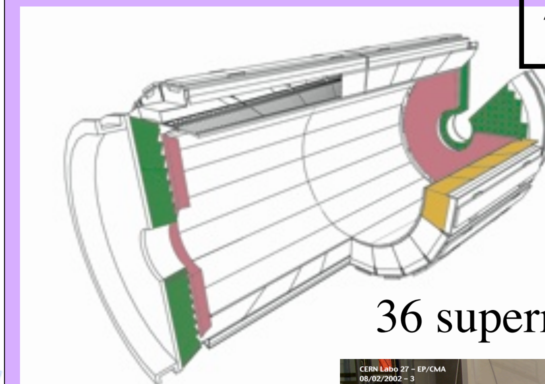
Drift Tube   Resistive Plate

Cathode Strip Chambers

Total weight : 12,500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla

ECAL Scintillating PbWO4 crystals

75848 Xtals



36 supermodules

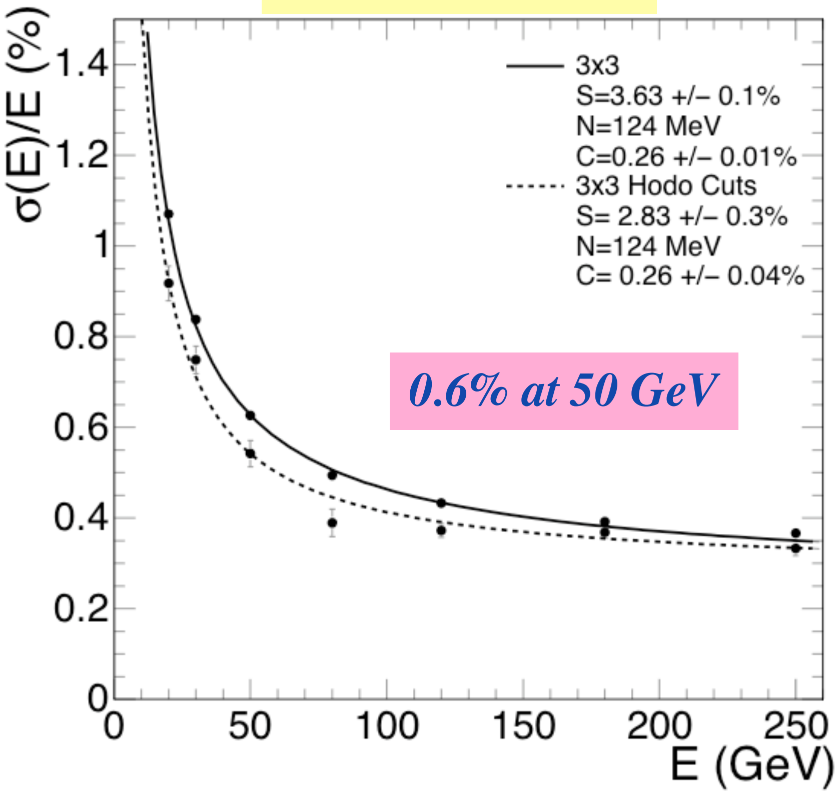
4 dees

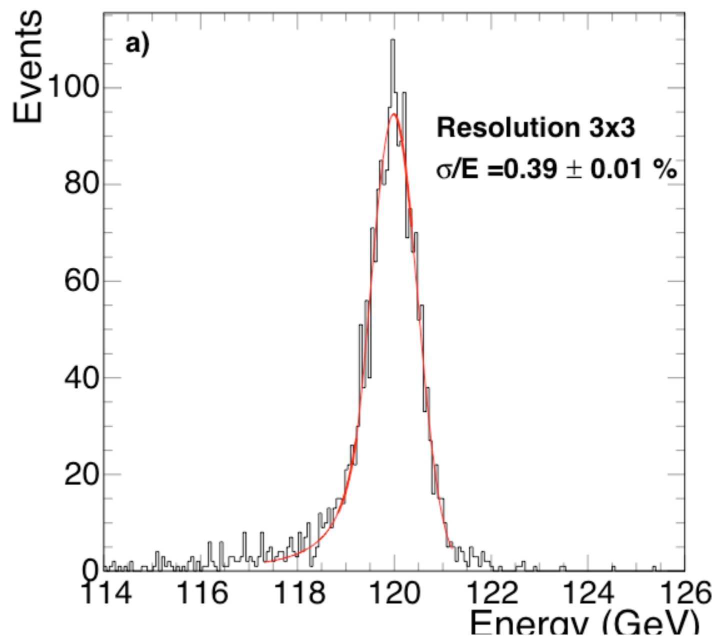
$|\eta|<2.6$

2x5 Xtal modules

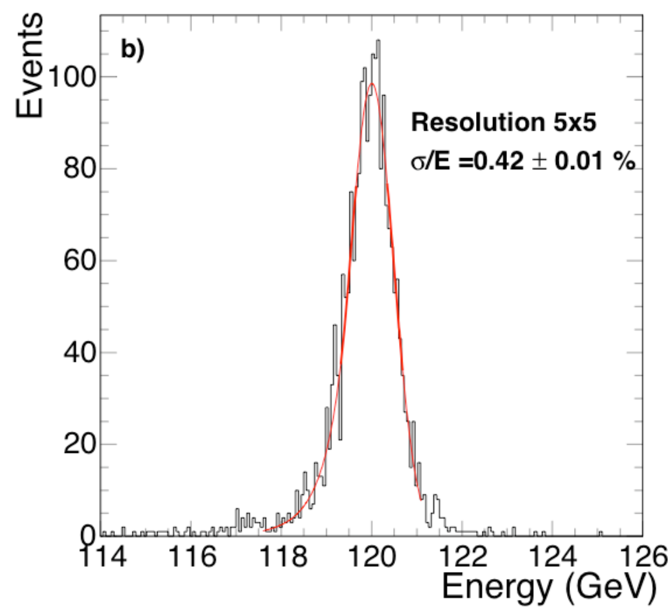
CMS PbWO4 Calorimetry

Energy resolution

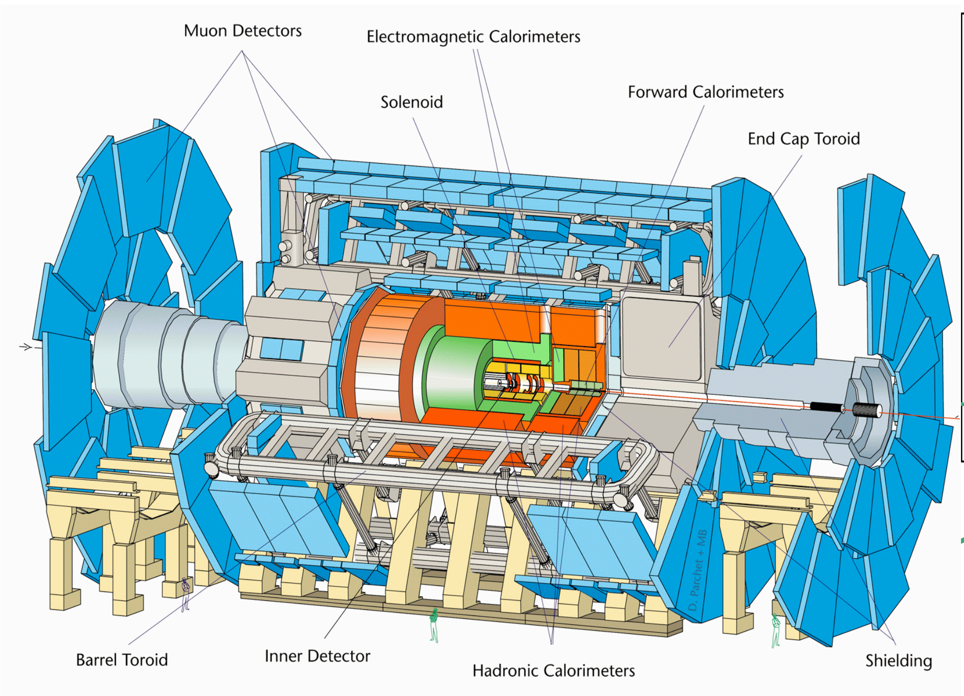




$$\frac{\sigma(E)}{E} = \frac{2.8\ \%}{\sqrt{E}} \oplus \frac{124\ \mathrm{MeV}}{E} \oplus 0.26\ \ \%$$



The ATLAS Detector

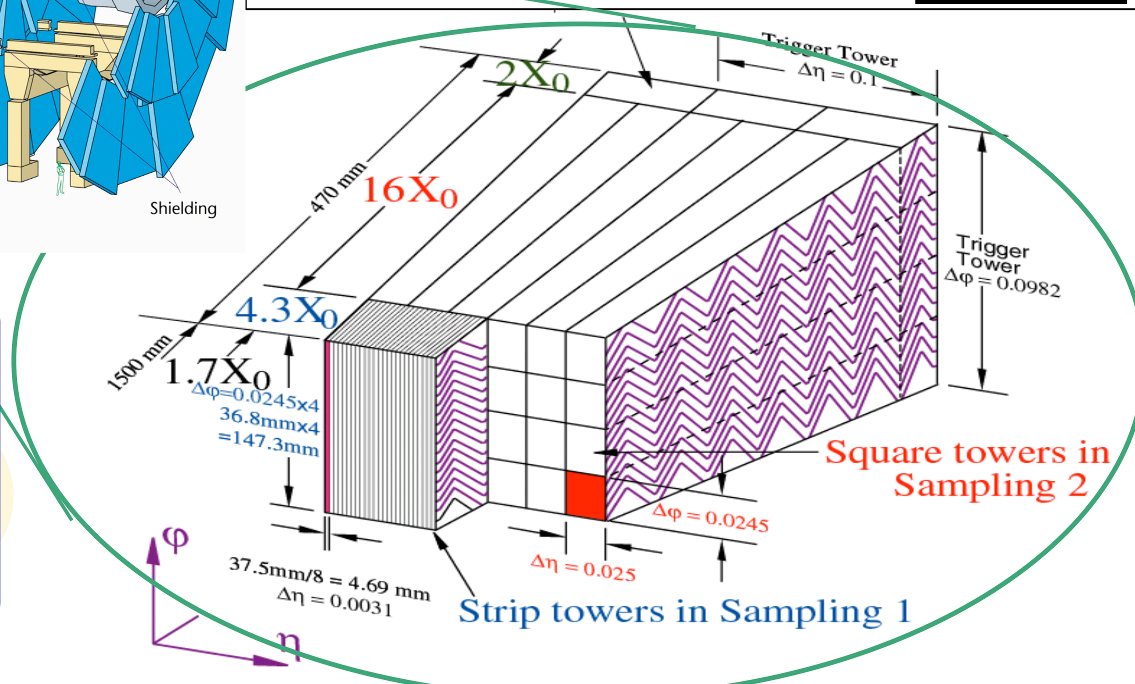


General requirements for the LArEM:

- ✓ $\sigma_E/E = 10\%/\sqrt{E} \oplus 24.5\%/E \oplus 0.7\%$
- ✓ linearity better than 0.5% up to 300 GeV
- ✓ shower direction with s_q ~50 mrad / √ E
- ✓ fine granularity of 1st compartment
- ✓ shower shape measurement

$|\eta|<2.5$

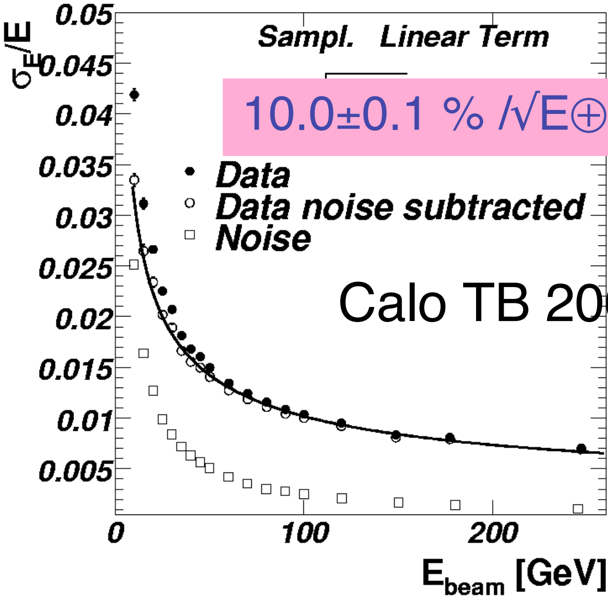
Layer	Granularity ($\Delta\eta \times \Delta\varphi$)
Pre-sampler	0.025 x 0.1
Front	0.003 x 0.1
Middle	0.025 x 0.025
Back	0.05 x 0.025

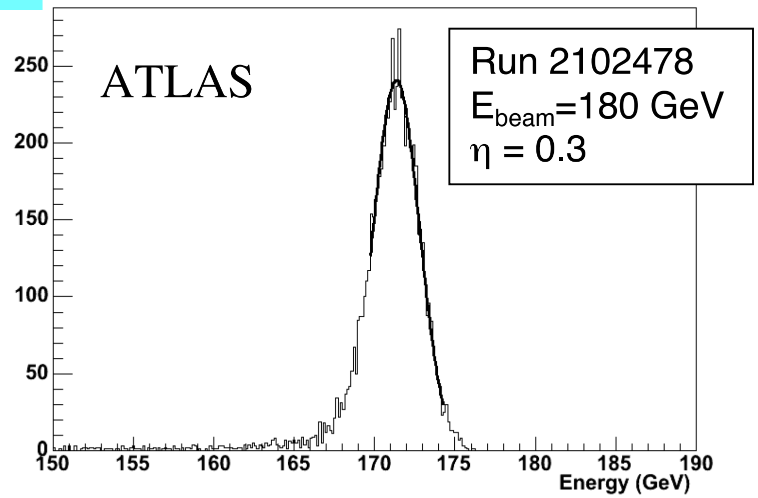


ATLAS LAr calorimetry

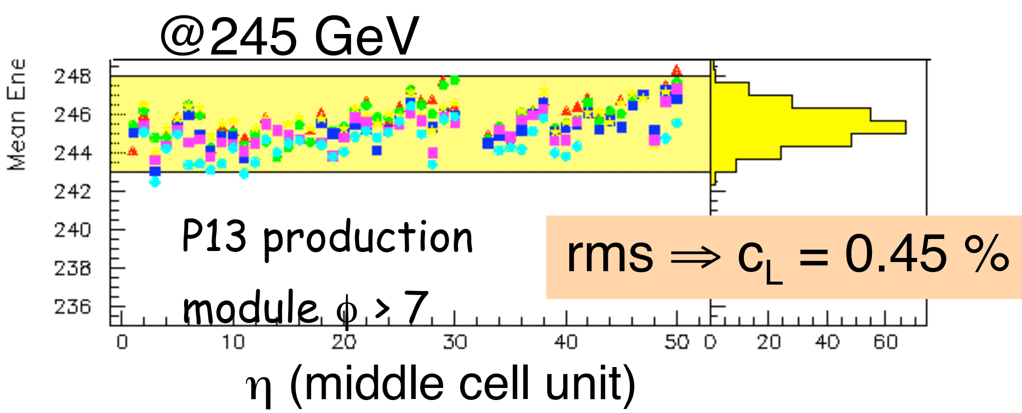
Energy resolution

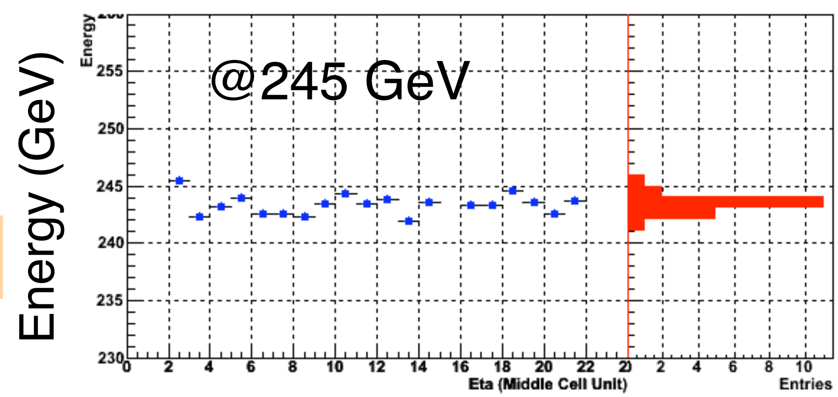
CTB 2004 (preliminary)





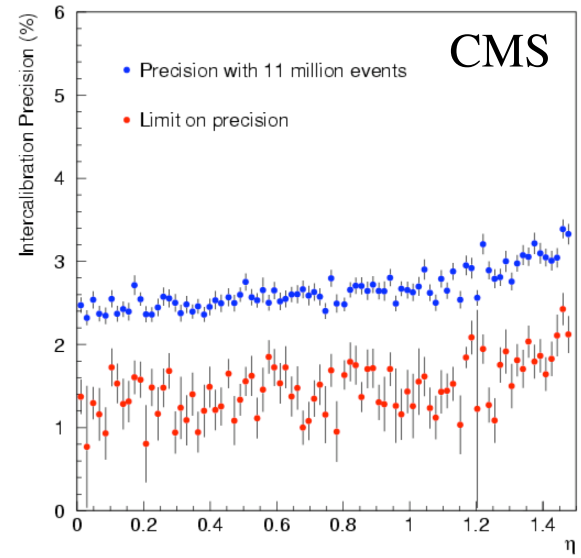
Constant term

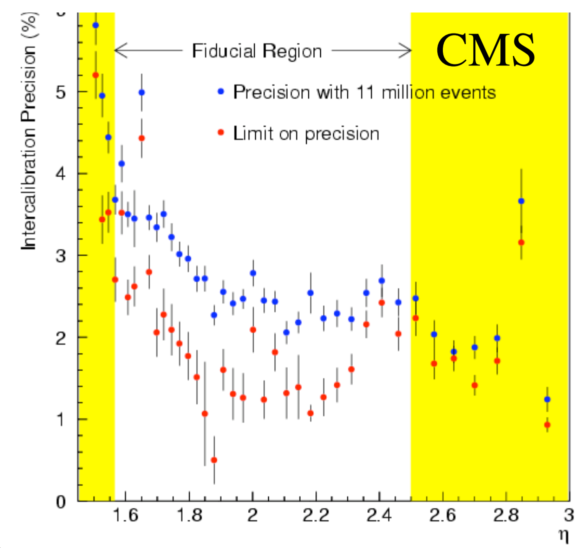




Intercalibration: phi symmetry

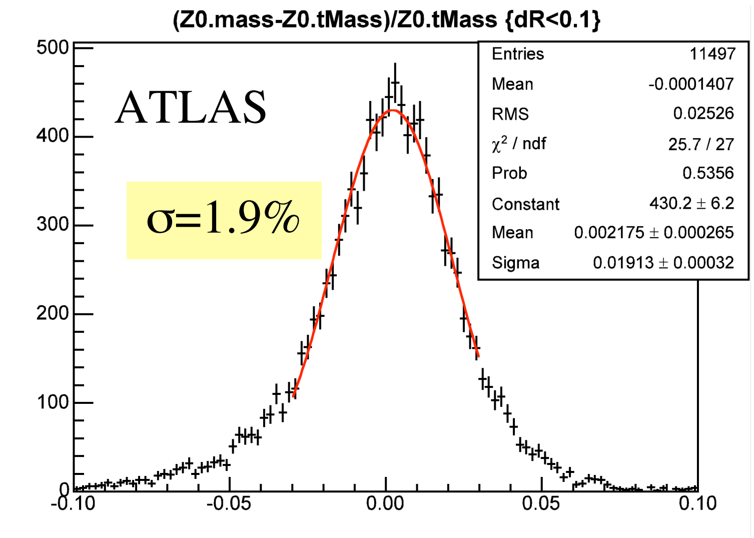
- Startup scenario: use single jet triggers
  - Previous study using min. bias events
  - Jets closer to the relevant energy scales
- Reach 2-3% depending on eta
  - In only few hours assuming full trigger bandwidth allocated to phi symmetry calibration
- To be complemented by a method to intercalibrate the phi rings
  - e.g. $Z \rightarrow ee$
  - Which therefore needs to run on less regions
- Limited by the tracker material non uniformity in ϕ

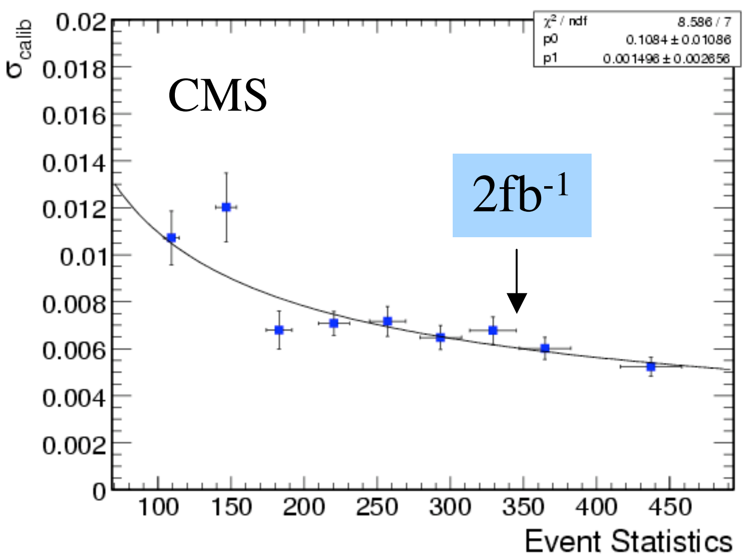




Intercalibration: Z→ee

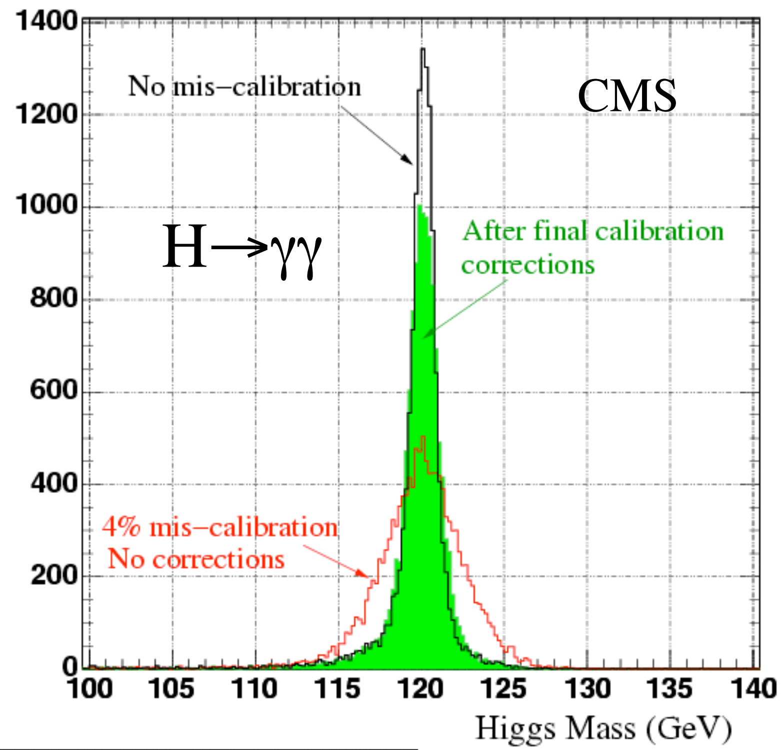
- Intercalibration of regions at start up using kinematical constraint
- Select low radiating electron pairs
  - Main difficulty
  - Efficiency of 5.6% for golden-golden Z's
- 0.6% after $2fb^{-1}$ (CMS)
  - Starting from a mis-calibration between rings of 2% and within rings of 4%
    - As result of lab measurements and phi symmetry

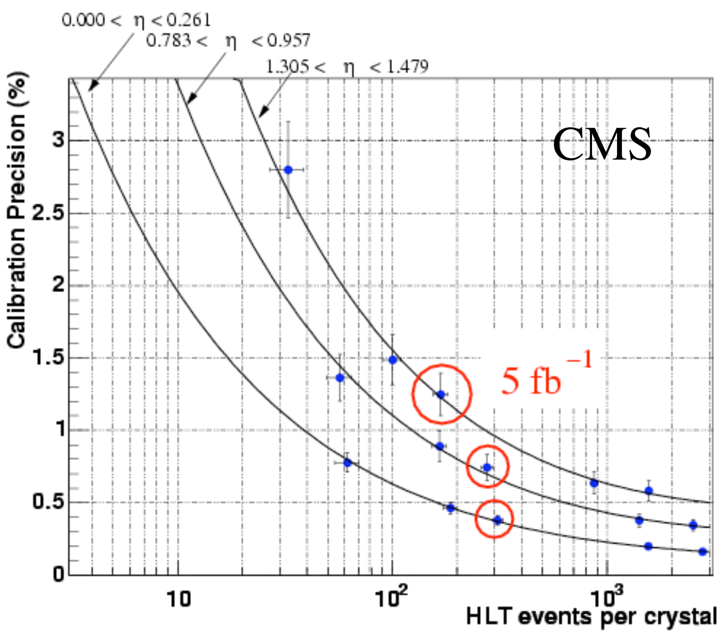


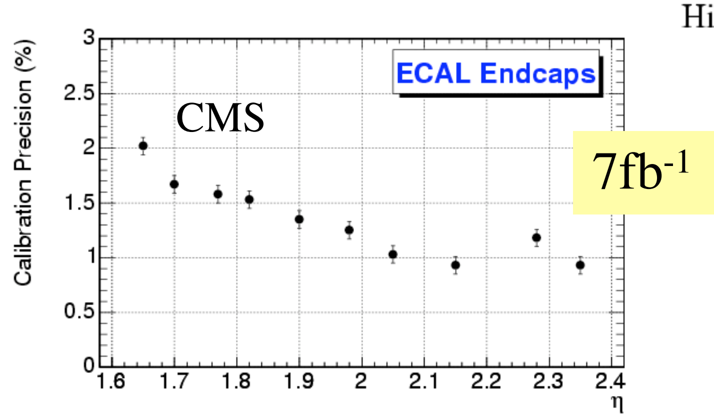


Intercalibration: W→eν

- Intercalibrate in small regions
  - use peak of E/p to intercalibrate the regions
- Going from electron to photon will require MC

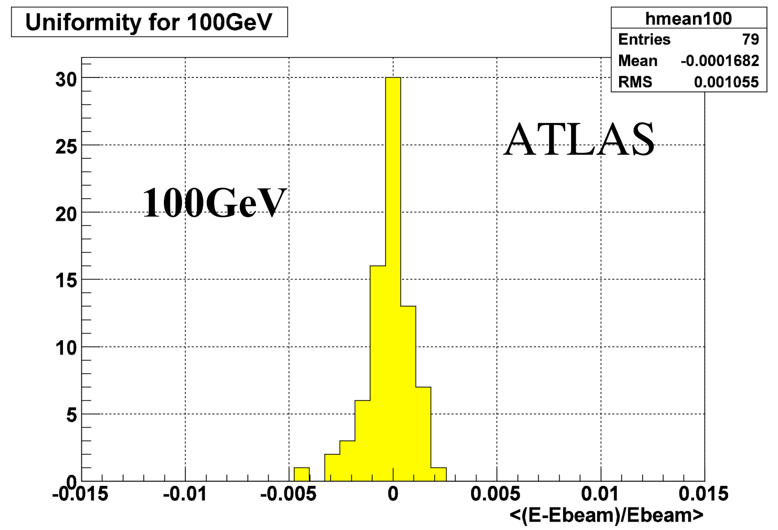


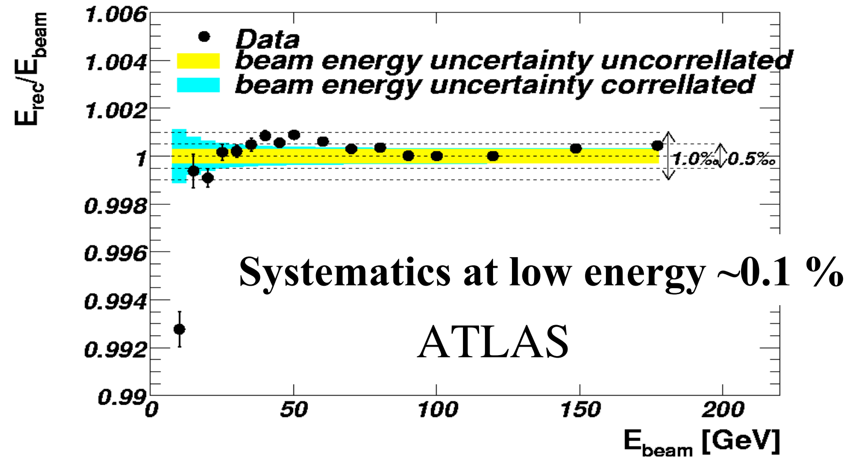




C. Charlot, HCP2006, Electron and photon ID at ATLAS and CMS

Cluster energy corrections





0.1%-0.2% spread from 10GeV to 1TeV over all eta!

Testbeam: Achieved better than 0.1 % over 20-180 GeV:

- done in one η position in a setup with less material than in ATLAS and no B field

-No Presampler for η >1.8

$$E^{rec} = \boxed{(a(E) + b(E).E_{PS}^{Vis}} + \boxed{c(E)(E_{PS}^{Vis}.E_1^{vis})^{0.5}} + \boxed{d(E).\sum_{i=1,3} E_i^{calo})}.\boxed{(1 + f_{leak}(depth))}.f_{brem}(E).f_{cell\ impact}$$

E loss upstream of PS

E loss PS and calo

calo sampling fraction+ lateral leakage E dependent

Longitudinal leakage

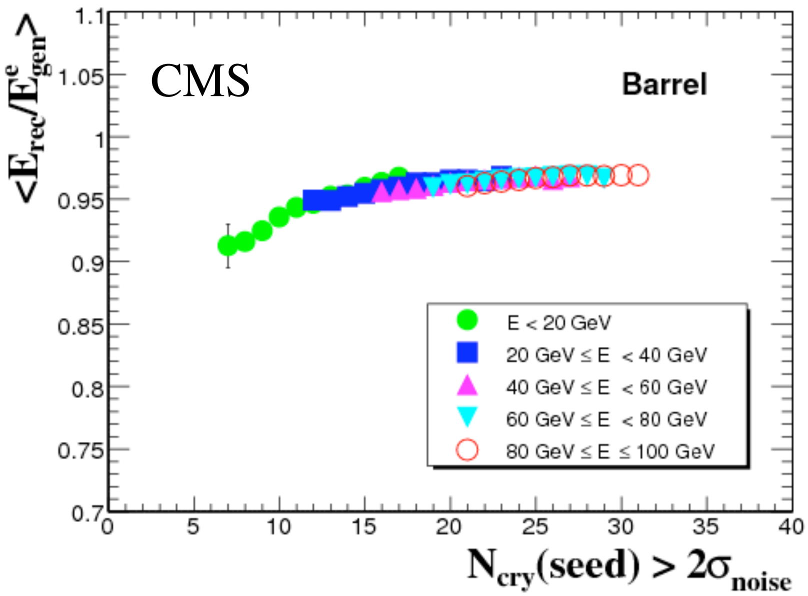
Cluster corrections

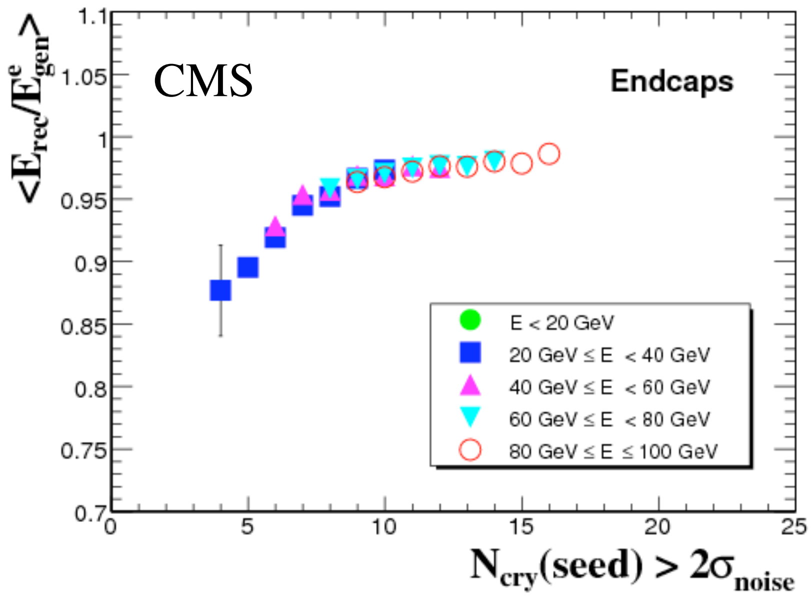
$E_{corr} = E_{sc} \,.\, F(N_{cry}) \,.\, f(\eta)$

$E_{endcaps} = E_{presh} + E_{corr}$

Algorithmic corrections ultimately tuned on $Z \rightarrow ee$ data

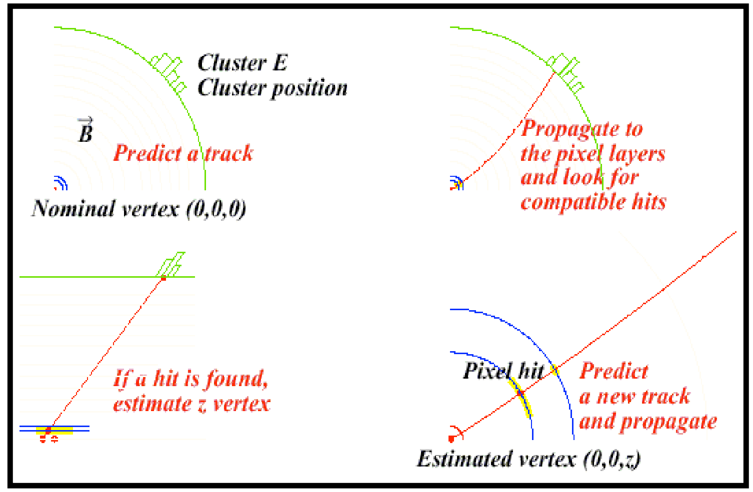
- $F(N_{cry})$: containment, ECAL only correction
- $f(\eta)$: energy lost, residual η dependence, depending on track-cluster patterns (e classes)





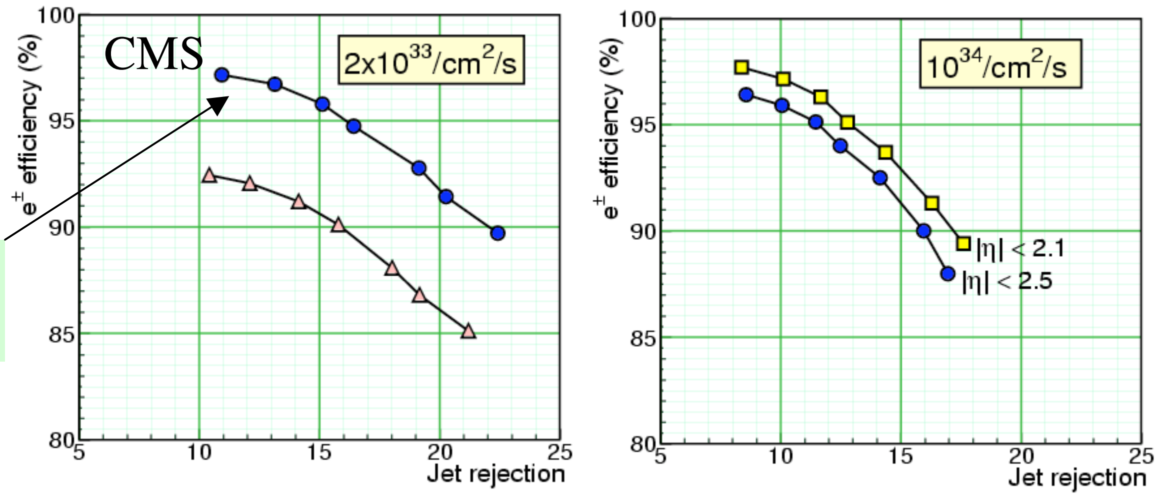
ECAL driven reconstruction

- Electrons and photons starts with clusters in the ECAL
- For electrons, associate the cluster with a track
- Pixel match in CMS
  - Same algo for offline and HLT
- Low p_T algo starts with tracking



HLT 2.5

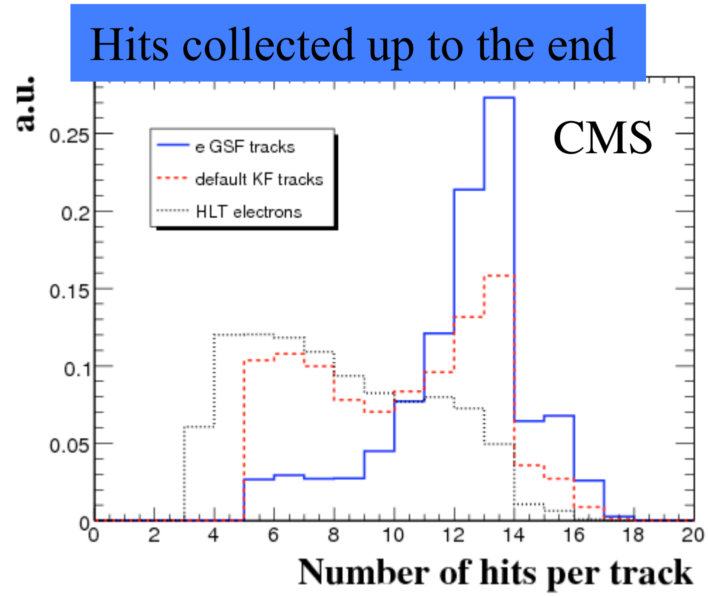
Full PIXEL detector

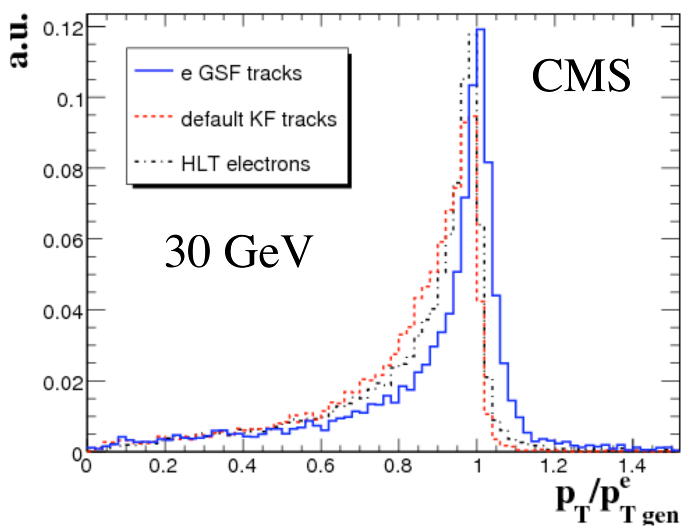


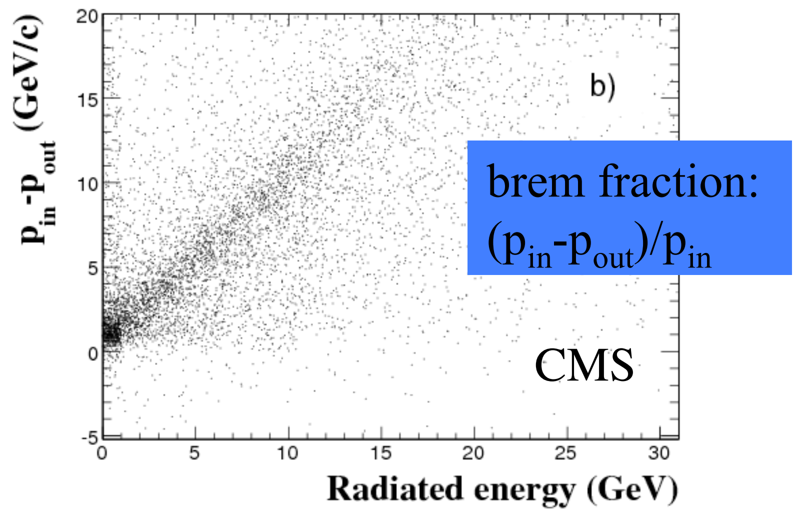
C. Charlot, HCP2006, Electron and photon ID at ATLAS and CMS

Electron tracking

- CMS in-out GSF electron tracking
  - Energy loss for electrons is highly non gaussian
  - Bethe-Heitler energy loss modeled by several gaussians
  - Use most probable value of the components pdf instead of mean
  - Meaningful momentum @ last point

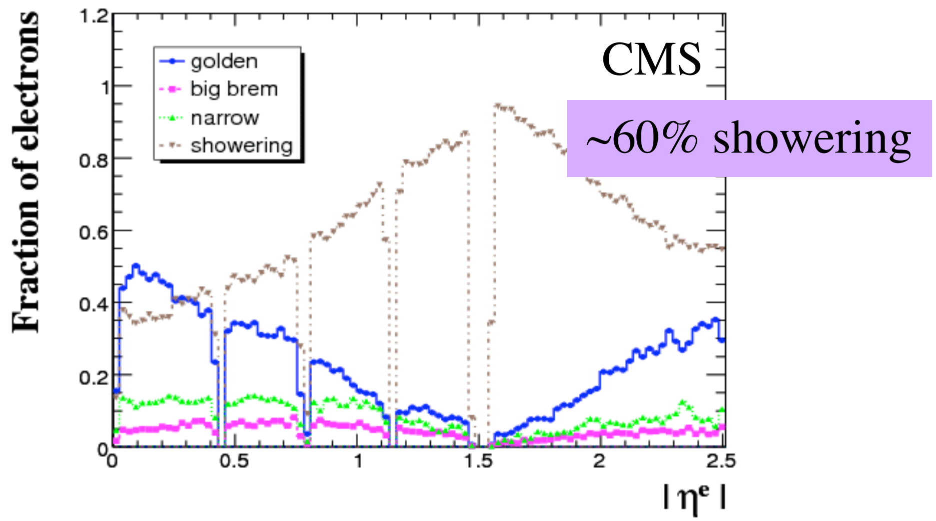


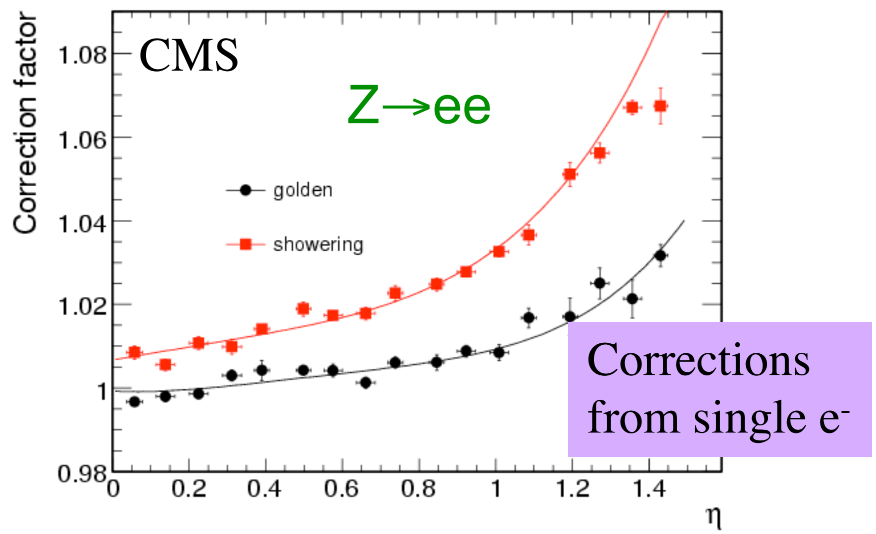




E-scale corrections, e classes

- Different track-cluster patterns due to brem in tracker material
- E-scales corrections depend on classes
  - « golden electrons »
    - Good E/p and phi match
    - Low brem fraction
  - « big brem electrons »
    - Good E/p match
    - High brem fraction
  - « narrow electrons »
    - Good E/P match
    - Intermediate brem fraction
  - « showering electrons
    - Bad E/Pmatch, brem clusters
- Tuned using Z→ee data
  - Still MC needed for low p_T region

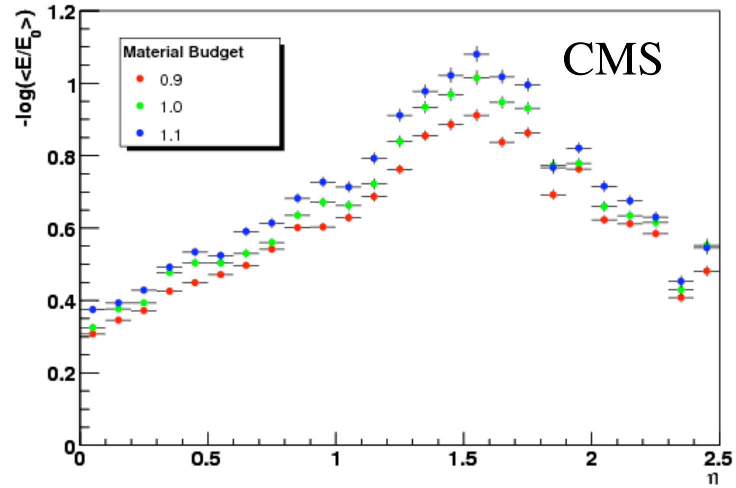


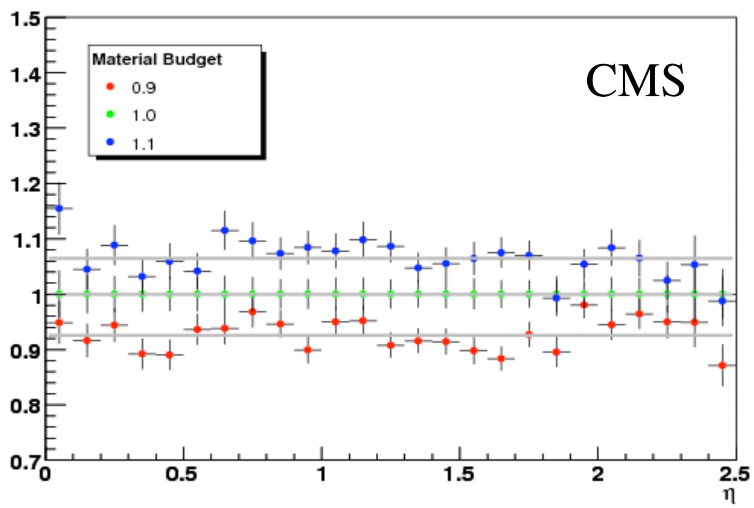


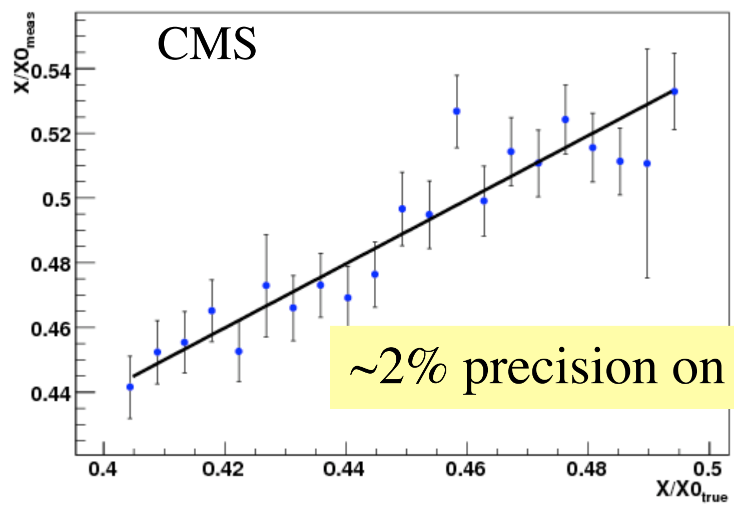
Material from data

- Location from X-ray of the detector using conversions
- Amount from variables sensitive to material integral
  - E/p distribution
  - use brem fraction from GSF e^- tracks

$$\langle X/X0 \rangle \sim -\ln(1-f_{brem})$$



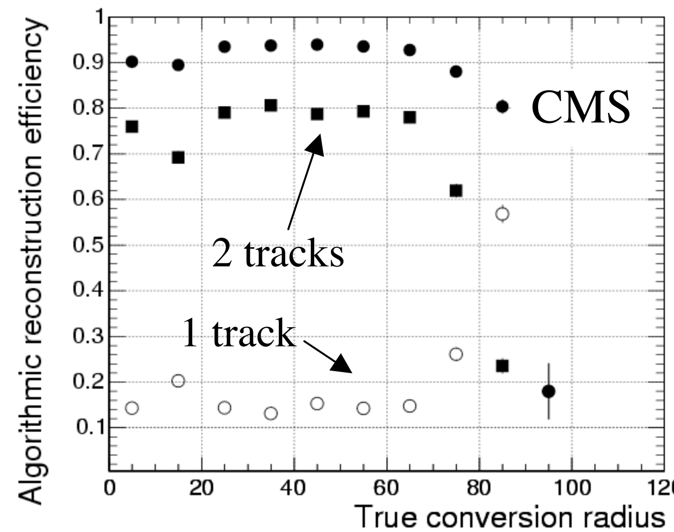


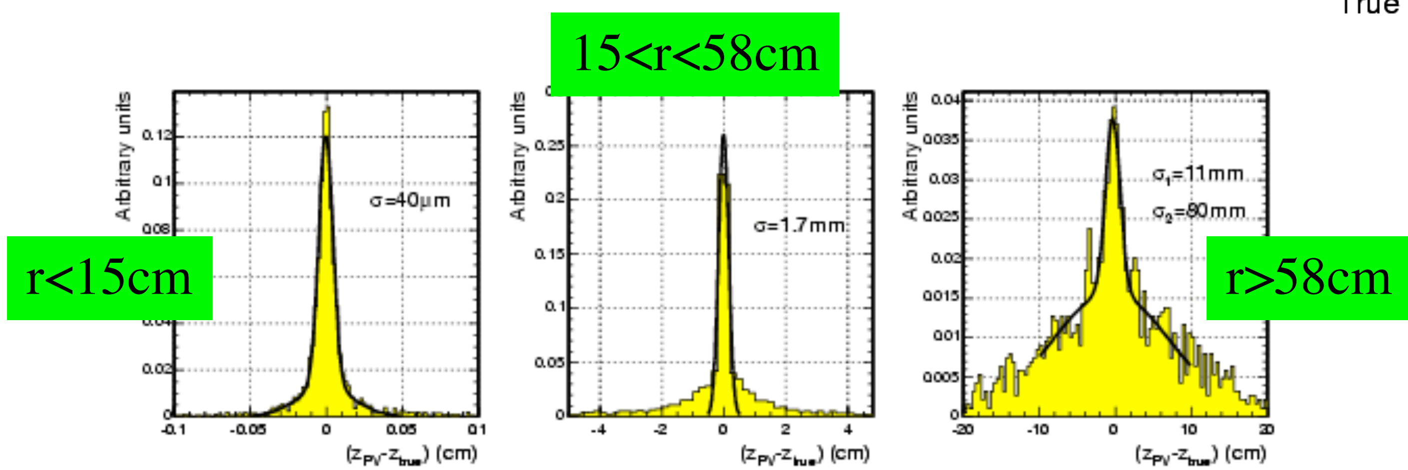


~2% precision on X/X0

Photon conversions

- ECAL driven inward seed/track finding
  - Followed by outward seed/track finding
- Pairs of opposite-charge tracks fitted to common vertex
  - Parameters refitted with vertex constraint
- Photon momentum from the tracks
  - Determines the primary interaction vertex





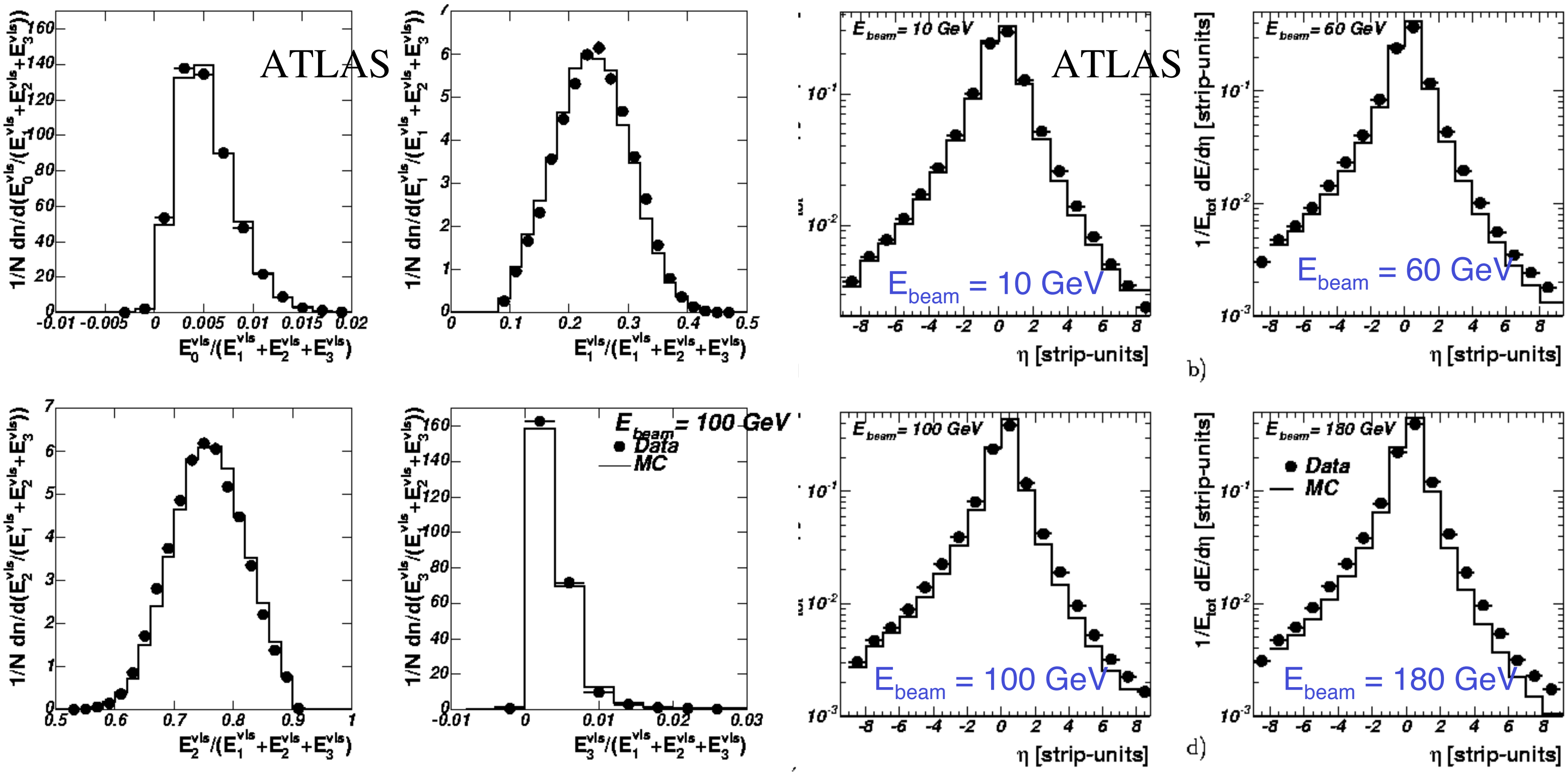
(barrel)

Shower shape

LArEM beam test 2001-2002

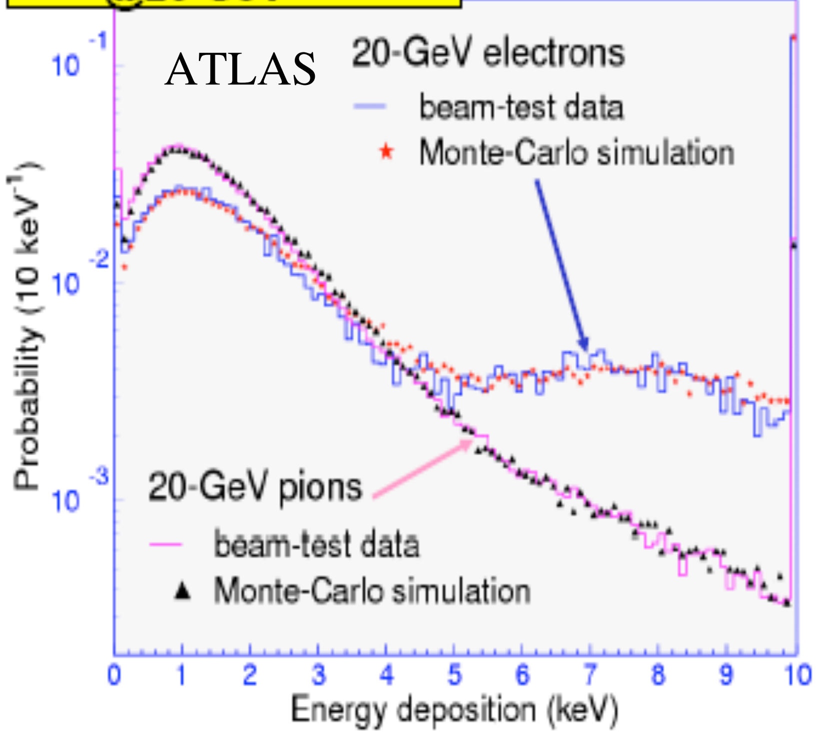
Comparison between data and G4 standalone simulation

Longitudinal development — Lateral development



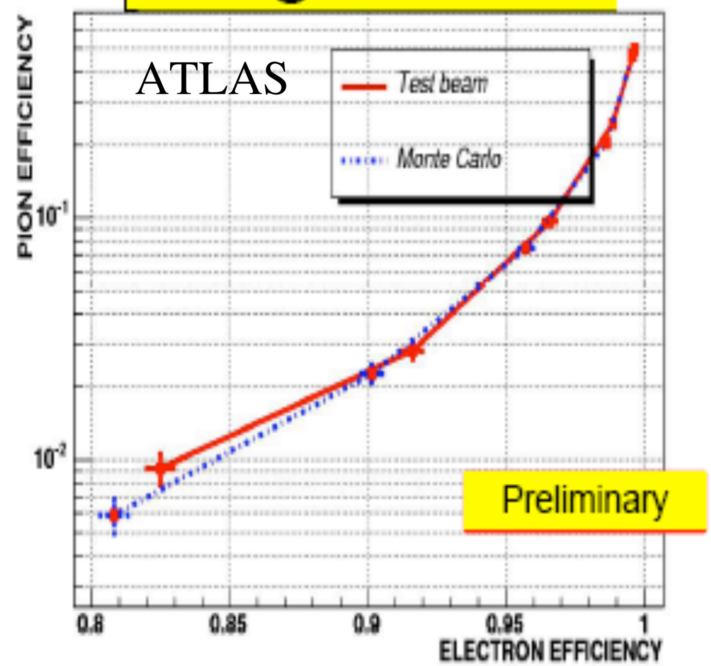
e^{-}/jet separation using TRT

Results from TB 2002 @20 GeV



Typical TR photon energy depositions in the TRT are 8-10 keV
Pions deposit about 2 keV

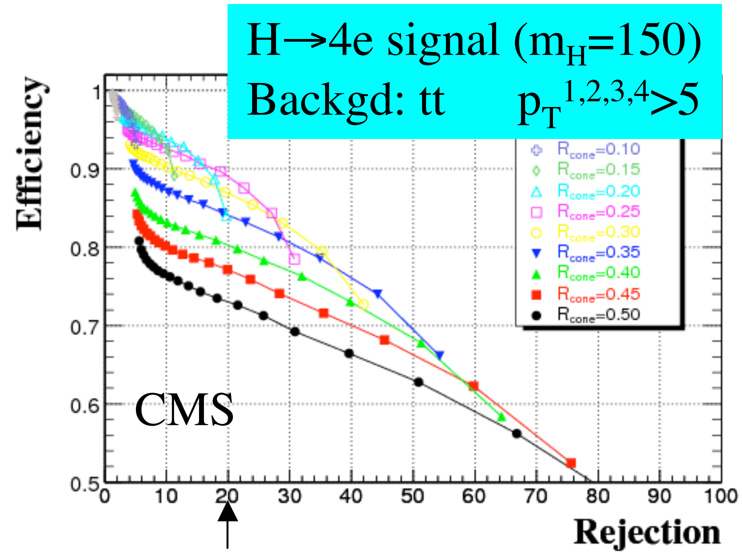
Results from CTB2004 @9 GeV

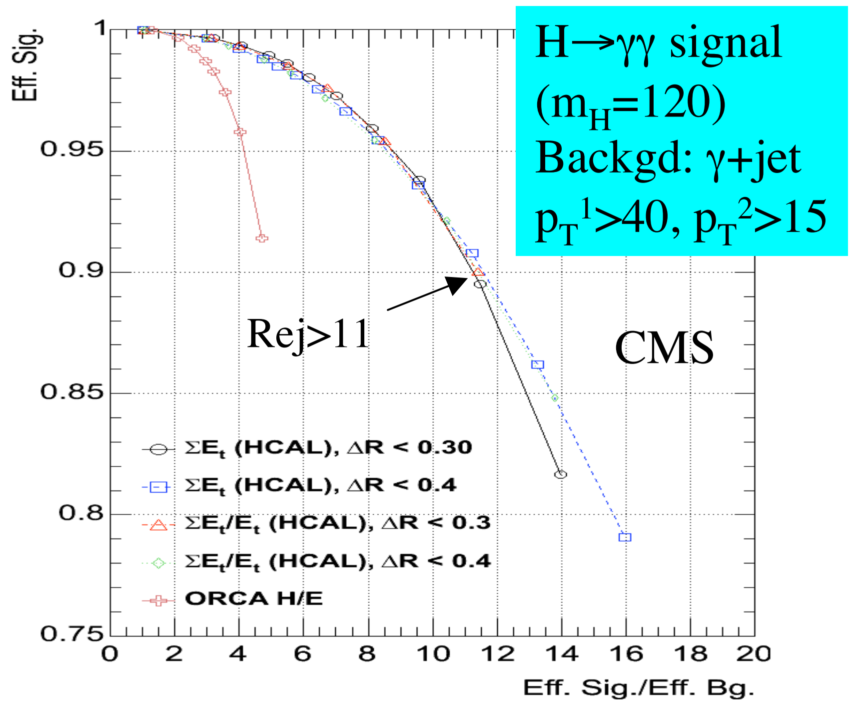


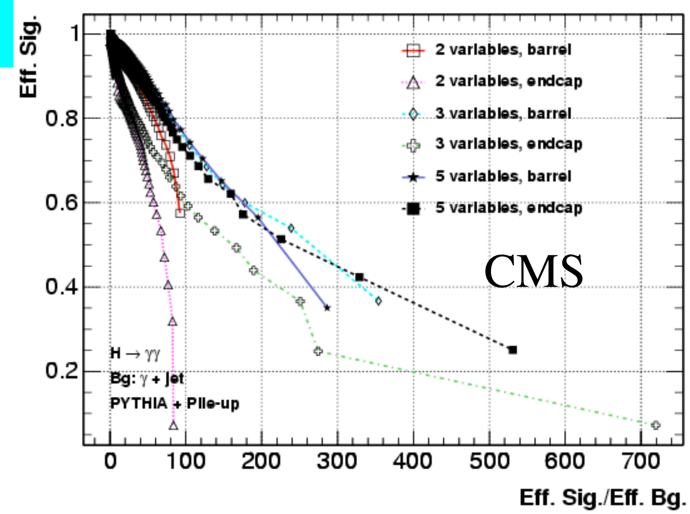
90% electron efficiency
2×10^{-2} pion efficiency
(#energy than TB2002)

e/jet,γ/jet separation: isolation

- Isolation is a very powerful tool to reject jet backgrounds
  - Track based isolation
  - Calorimeter isolation
  - Combined isolation

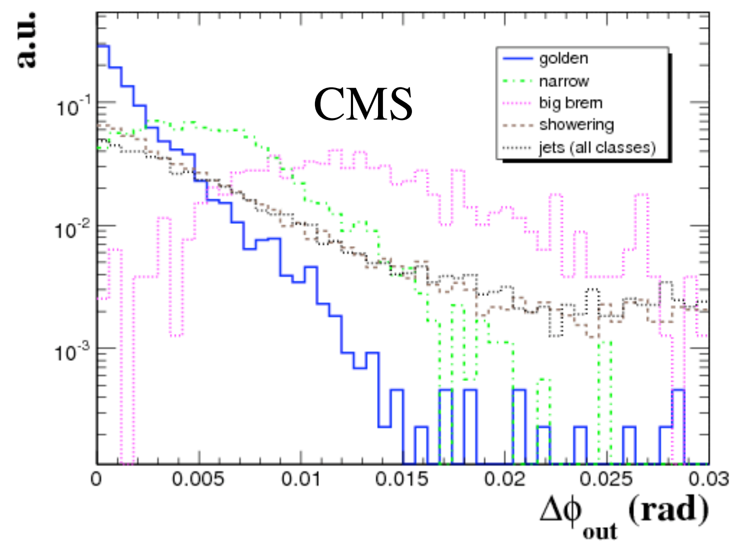


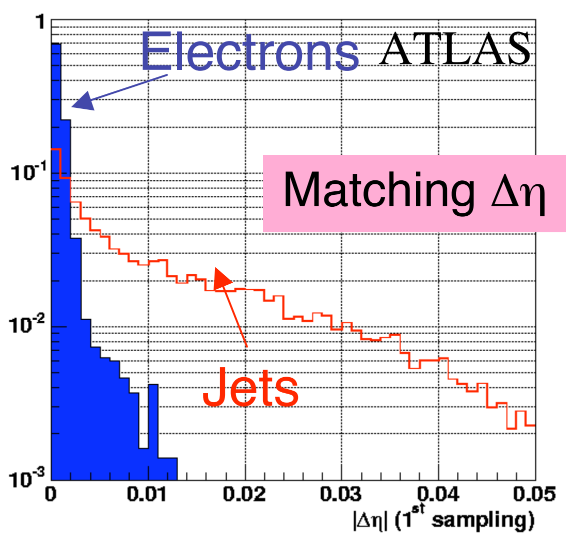


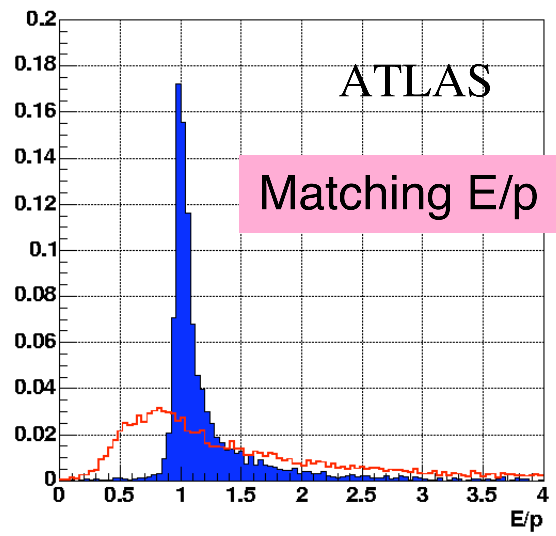


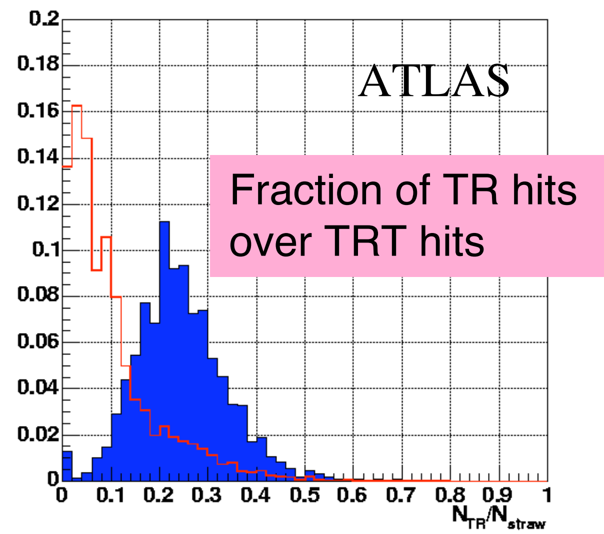
Electron identification

- Electromagnetic object from calo information
- Track matching ($\Delta\eta$, $\Delta\phi$), E/p
- Use of transition radiation (ATLAS)
- Isolation
- ID per class (CMS)
- Identification of conversions





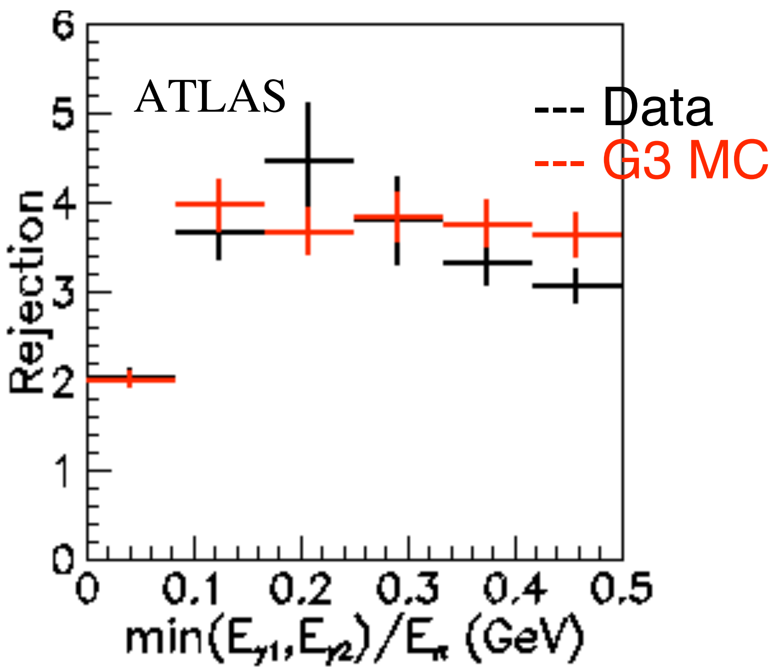




π^0/γ separation

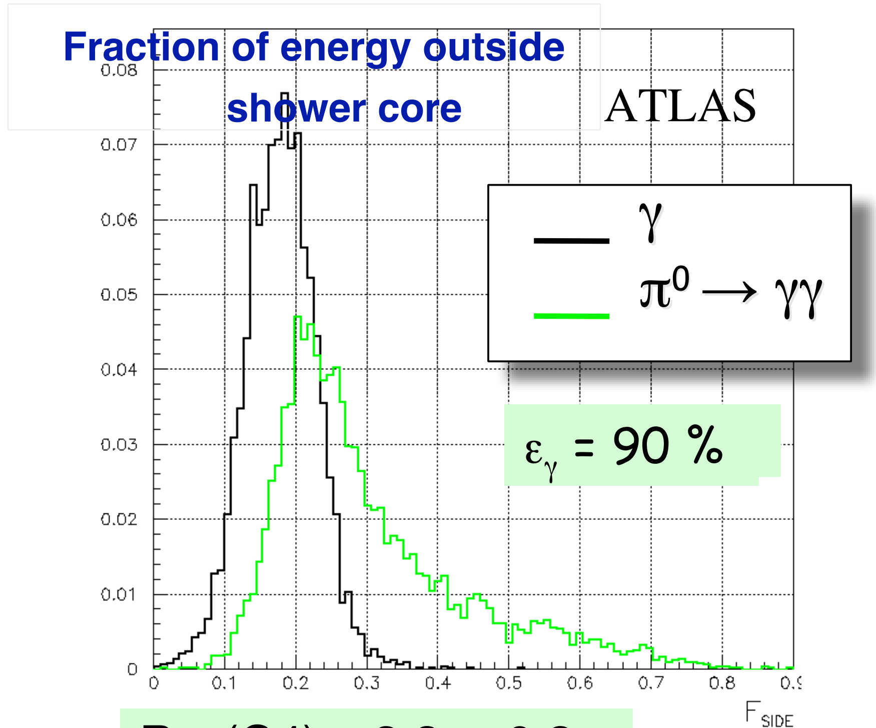
- Once isolation has been applied, only jet with little hadronic activity remains

Results from TB 2002 @50 GeV



R_{p0} (data) = 3.18 ± 0.12 (stat)
R_{p0} (MC) = 3.29 ± 0.10 (stat)

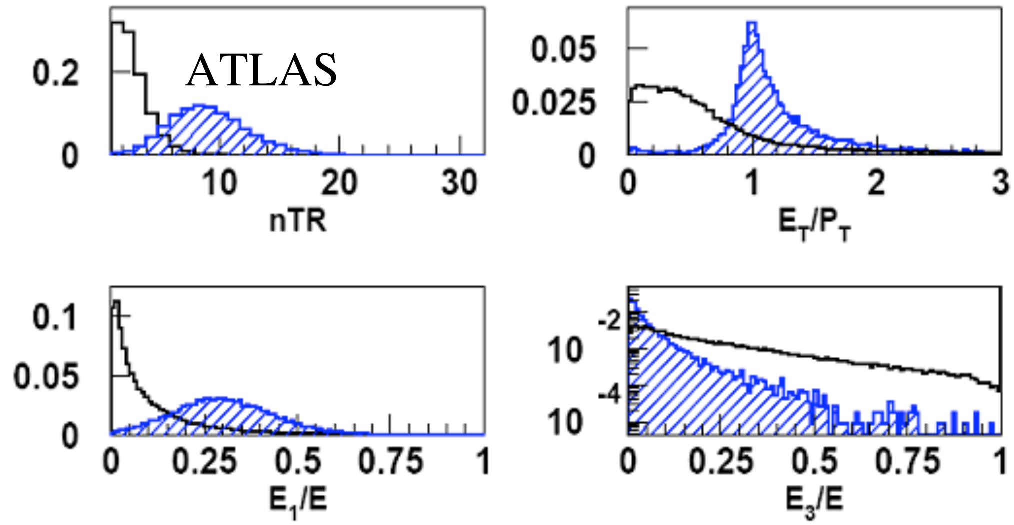
Results from G4 full simulation

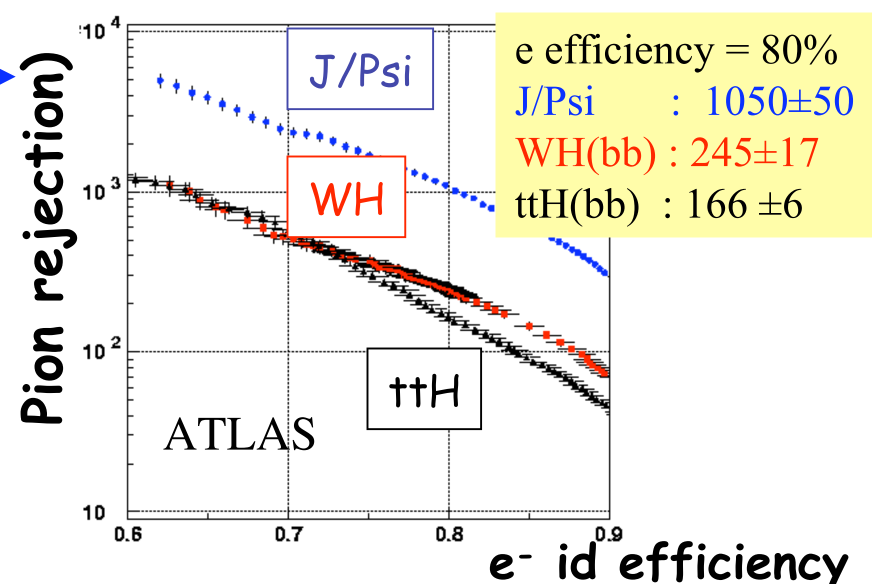


R_{p0} (G4) = 3.2 ± 0.2

Electrons from b's

- Reconstruction of electrons close to jet is difficult
  - Dedicated algorithm required
- ATLAS low p_T algorithm:
  - Build cluster around extrapolated track
  - Calculate cluster properties
  - pdf and neural net for ID
- Performances on single tracks →
- Soft e^- b-tagging efficiency
  - ATLAS: 60% for R=150 (WH)
  - CMS: 60-70% above 10 GeV miss rate ~1.5% (tt and QCD)





Summary

- Electron and photon ID are essential ingredients for new physics at LHC
- In situ calibration procedures are established
- Material budget is a key issue
  - Impact the reconstruction efficiency
  - Degrades performances
- Isolation is a very powerful tool
- Final ID using shape and match variables
- Dedicated algorithms needed for e- from b's